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A THEATRE BALLISTIC MISSILE (TBM) COUNTERFORCE CONCEPT

by

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13. ABSTRACT *(Maximum 200 words)*

The purpose of this report is to first give a fairly comprehensive list of the world's tactical ballistic missile systems and then to discuss some of the options available to find the TBM's before they can be launched. The focus of this report is primarily on finding the Transported Erector Launchers by the use of unattended ground sensors.

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I. Introduction

This report resulted from discussions of a group of officer students of the Combat System Science and Technology Curriculum at the Naval Postgraduate School in connection with a course on weapon system proliferation issues held in the fall quarter of 1993. The student group made several visits to the Nonproliferation, Arms Control, and International Security Organization at Lawrence Livermore National Laboratory where they learned much about new sensor technologies which may have significant bearing on aspects of the tactical ballistic missile problem.

The purpose of this report is to document the ensuing discussions which the students had with regard to the threat by proliferation of missiles, giving a fairly comprehensive list of the world's tactical ballistic missile (TBM) systems and then to discuss some of the options available to find these TBM's before they can be launched. The focus of this report is primarily on finding the Transported Erector Launchers (TELs) before they have launched at TBM.

As is evident from the Desert Storm War, the TELs are almost impossible to find. They can go out into remote areas and blend in with the surroundings making them virtually invisible. There have been several advances in the technology of sensor systems which may be able to be used to aid in the detection of these TELs. This report will address some of the advances in sensors and how they may be used to detect transported launchers.

II. **Proliferation**

The purpose of this section is to provide the reader with some basic knowledge of the world's tactical ballistic missile (TBM) systems. This survey includes missile systems capable of delivering warheads of at least 250 kg to ranges between 35 and 3000 km. There is no classified material in this section. We did consult classified sources, but where a piece of classified information exists, there is an asterisk and a number. The number refers to the source of that information as listed in the accompanying bibliography of classified sources.

Appendix A is a list of countries that are known to possess tactical ballistic missile systems. Ninety-five percent of this information came from Duncan Lennox's article, "Missile Race Continues", in the 23 Jan 93 issue of "Jane's Defence Weekly".[1] The other five percent came from equally open sources. For a more accurate and detailed account, including estimated numbers, the classified section of the NPS library may have what is required for certain countries. This report provides some idea of which systems each country probably has.

Appendix B lists TBM's in service and some of their characteristics. There are many blank spots in this table. It is not intended to be a complete work, but a framework upon which others can build. Some data fields were not available for any missile system, but are included in the hope that data may become available. Some TBM systems have the *# code right beside their name. These are systems that have potentially useful information far beyond the scope of this work.

In the following section Unattended Ground Sensors (UGS) and their cueing mechanisms will be discussed.

Cueing is a very important part of engaging a TBM, both before and after launch. There are two types of cueing which we will address. The first is called simply "cueing" and refers to alerting as to when a TBM launch has occurred or when a TBM launcher has been detected. The second we will call "preliminary cueing" and this deals with methods by which we can determine threat areas and drop UGS into place to provide warning.

There are several aspects to cueing. First, the cueing has to be relatively accurate, i.e. a small false identification rate is required. Because of the complexity of military operations, there has to be a high confidence that the cueing signal is accurate. Second, the cueing has to be timely. The time of flight for a TBM varies greatly, thus making it imperative that the data be relayed to the proper assets in a very timely manner. The data has to be real time.

III. **Counterforce Surveillance**

The Ballistic Missile Defense Office (BMDO) initiative for tactical missile defense (TMD) proposes a counterforce surveillance concept composed of airborne/space based sensors and ground based sensors. Airborne and space based sensors include JSTARS, U-2 intelligence, electronic support measures aircraft, TENCAP, Boeing 757 Flying Test Bed, and other reconnaissance platforms. Ground based sensors include unattended ground sensors (UGS) and special operations forces.

Of particular interest is the methodology to be used to determine initial UGS deployment to achieve effective counterforce surveillance. Its deployment obviously relies on "indicators" of suspected activity in a given area. These "indicators" come from preliminary cueing.

When considering preliminary cueing for UGS deployment it is instructive to first look at the ASW analogue to the UGS: the sonobuoy.

As with a UGS array, cueing for initial sonobuoy deployment is critical because of limited assets as well as the limited detection capabilities of the sensors. Sonobuoys are relatively expensive and must be deployed by an airborne platform. Their deployment is usually triggered by some other cueing mechanism, whether it be SOSUS, TAGOS or some other ASW platform. This concept is critical. With thousands of square miles of ocean, sonobuoy deployment cannot be random. It must instead rely on a triggering mechanism to commence the localization process. There has to be a starting point from where a search can proceed.

This challenge is the same for initial UGS deployment. A UGS array obviously cannot extend throughout a theater of operations; it may only focus on a concentrated area. The decision as to where to focus on is of the utmost importance.

To address this issue, it is useful to exclude all areas in a theater of operations which cannot support TBM operations. This "negative search" methodology rules out those areas in which TBM operations would be impossible or highly unlikely.[2] Examples of such areas would be mountainous terrain or isolation from existing internal infrastructure such as roads. From the negative search model, tailored assumptions can be incorporated to accommodate the particular situation. Of course, such intelligence gathered prior to commencement of hostilities would be of great utility.

The exclusion of unlikely TBM operating areas, however, will still leave an expanse of territory where they can most definitely operate. A cueing mechanism in the operating area is now required to indicate suspected areas of activity: it will provide at least a starting point from where to begin the search. The mechanism may be as simple as a prior TBM launch in the area. This "flaming datum" strategy provided no success in the Gulf War. UGS assets, could, however, monitor future activity in the area.

Ideally it is desired to avoid the flaming datum strategy entirely and instead to focus on detecting TBM pre-launch activities. This includes TBM units, launch sites previously surveyed, logistics facilities and other fixed facilities where appropriate.

A. Preliminary Cueing Mechanisms

Cueing mechanisms to focus on TBM activity are manifested in 3 areas:

- Airborne sensors
- Tactical intelligence
- Space Based (Overhead) Sensors

In this context, tactical intelligence refers to analyzing current enemy activity, gathering data from prisoners of war and other sources of HUMINT, and analyzing prior TBM launch patterns and activity. It includes a significant degree of speculation.

Sensors, on the other hand, provide definite indicators of activity. A sensor may tell as little as a detection which is considered "anomalous" to the contiguous environment or it may tell as much as target identification and position, or most likely tell something in between.

The sensors which can be used for UGS preliminary cueing may be divided between "overhead" and "airborne" sensors. It may be useful to consider overhead sensors as national assets, while airborne sensors may be considered as theater based assets.

Of the numerous sensors which could provide cueing for UGS deployment, two cogent examples will be discussed: an overhead sensor (LANDSAT) and an airborne sensor (wavelength tunable video system).

B. **Overhead Sensor System Concept**

The Defense Support Program (DSP) is a classified overhead system which was designed to detect in the infrared region (i.e. missile launch). For the purposes of cueing for UGS deployment, a space based system would require optical scanners for imaging purposes.

A representative system could be expected to be constructed in two tiers. The first tier would involve a low resolution system and a broad search area. The first level of data acquisition would narrow the intelligence to potential target areas. The second tier, with high resolution, would allow concentrated search areas with a subsequent increase in data processing requirements.

Although there are DOD specific overhead systems, LANDSAT provides a useful unclassified illustration of the utility of satellite reconnaissance for this application. DOD assets may expect to have significantly enhanced capabilities.

The primary contribution of an overhead asset would be timely identification and tracking of events; specifically, mobile missile launchers over wide areas. Acquired data could also be used to develop a continuous record of vehicle movement for off-line analysis and accurate designation of TBM units, logistic bases, and fixed facilities for targeting purposes. Overhead sensors in this context are analogous to the regional localization of submarines using the SOSUS system.

The most recently deployed LANDSAT units operate at lower altitudes than their predecessors (approximately 700 km). They provide higher resolution, ease of shuttle recovery for modification and repairs, and improved repeat cycles (approximately 15 orbits per day over 16 days). The Global positioning System (GPS) enables a more accurate localization. Each satellite consists of two primary sensors; a multispectral scanner (MSS) and a thematic mapper (TM). These are sensors which operate primarily in the visible and infrared detection regions.

The MSS is a mechanical scanner with 82 m resolution on the earth's surface. The MSS conducts data acquisition via surface scan in strips (six line simultaneously) normal to the orbital path of the unit. Overlaps forward are 5.4% and 7.3% on the sides of the orbital track and the data rate is 15 Mbps. The TM is a mechanical scanner as well but provides a more refined 30 m ground resolution and dynamic range. These improvements are due to improved spectral, spacial, and radiometric characteristics. The TM scans (16 lines simultaneously) seven spectral bands which include blue, green, red, near IR, mid IR, and thermal. The data rate is about 85 Mbps. These general data are given to provide an unclassified estimation of asset capability.

In addition to the MSS and TM, other remote sensing technologies may be employed to enhance intelligence gathering capabilities. Examples include high resolution infrared spectrometers, IR Echelle grating spectrometers, and broad band LIDAR. These systems are currently being researched at the

Lawrence Livermore National Laboratory for possible use in implementation of weapons proliferation treaty enforcement. Some of these technologies could further enable an overhead system to detect and localize pollutants and vehicle emissions.

Acquired data may be directly transmitted to earth-based antenna receiving stations or via geosynchronous tracking and data relay satellites (TDRS). The TDRS satellites are high capacity communications satellites currently employed and leased to NASA. The dissemination of data is dependent upon the rate data fusion, analysis, processing, and other C3 system architecture characteristics.

The method of data dissemination would include a network for cueing other reconnaissance assets; specifically, airborne search sensors.

The advantages of a space based cueing system includes near global coverage of the earth's surface on a predictable basis. Digital imaging and computer processing increase the level of extractable intelligence. The system could be limited by atmospheric anomalies, darkness, and saturation problems in some of the bands depending on topography. However, the clear advantage to overhead space based systems is the ability to gather data covertly.

In the 1980's Iraq/Iran war, DSP monitored 100 exchanges of SS-1 Scud missiles between Iraq and Iran. In the 1991 Gulf War, the best two second generation DSP's were moved over the war region. The DSP's indentified general target are after only two minutes into a seven minute Scud missile flight. The DSP was able to localize the target area within six kilometers. The DSP was also able to provide a real time data link to the Patriot missile system for counterdefense. Both of the examples above show just how valuable DSP can really be for preliminary cueing.

C. Airborne Sensor System Concept

The wavelength tunable video system is one example of the airborne sensor concept. This system was developed by the Lawrence Livermore National Laboratory.[3] As its name implies, this system can be used over a continuum of wavelengths for data acquisition. The system uses a tunable filter which provides a multispectral imaging capability, with high resolution and medium range resolution. The filters are electronically tunable at video rates.

Reflected light from objects passes through a camera lens, a tunable filter, an image intensifier, and into a charged couple detector (CCD) camera. The image is broken down by pixels, processed, and sent to either a monitor or optical storage.

The system may be employed to scan an area to search for known spectral signatures, known spectral shifts, or unexpected spectral features or shifts.

If the wavelength(s) corresponding to a specific activity is known, the system is tuned to scan on that one wavelength. A vehicle, for example, may radiate on a specific wavelength. Effluents and pollution may be detected in bodies of water. A heat source radiates wavelengths in the IR spectrum. Camouflage will radiate at different wavelengths than that of the surrounding flora it is attempting to blend into. Images that are indiscernible to the human eye can be found through the system by breaking down the radiating electromagnetic spectrum into discrete wavelengths.

If specific activity is unknown, which is often the case, the system may be utilized to compare the same area after a duration of time. Images may then be processed to show any differences between two snapshots in time. The differences between the snapshots may provide indicators of certain types of activity. For example, stressed foliage which may appear unchanged in the continuous visible spectrum may exhibit distinct changes under specific wavelengths over time.

Video processing of data may also be used to produce subtraction processed images, which compare the raw images of wavelengths of close proximity. For example, a tank hidden in brush becomes visible when the subtraction processed image is produced between the differences of raw images.

In regards to UGS cueing, the wavelength tunable video system could be used for several applications:

- Detection of stressed foliage
- Remote tracking of vehicle (or other signature specific platform)
- Movement or disturbance of earth
- Detection of vehicular or foot traffic
- Detection of disturbances in remote areas

- Detection of atmospheric vents for underground covert facilities.

As demonstrated, a major advantage of this system is that an acquisition profile can be tailored for specific detection scenarios.

This system is lightweight and affordable (consisting of primarily off the shelf hardware). While the existing prototype is ground based, the second generation model currently under design will be adaptable to an airborne platform. However, the aircraft must fly at relatively low altitude in order scan a given area. This may not be feasible due to the location of or enemy activity within the desired scan area.

An attractive alternative is to adapt the wavelength tunable video system for use on a remotely piloted vehicle (RPV). Mounting on an RPV would permit investigation of areas in enemy territory deemed too dangerous for low altitude aircraft reconnaissance. An RPV could fly lower and slower than an aircraft, permitting a more detailed examination of the scan area. The on station time would be significantly greater than that of an aircraft. Both risk and expense would be minimal. While data could be extracted upon RPV recovery, real time video could be obtained by use of a data link.

IV. **Unattended Ground Sensors (UGS)**

Now that we have seen what sensor suites are available for the cueing of deployment of unattended ground sensors, we will turn our focus to the ground sensors themselves.

A. **UGS Pros and Cons**

We will first examine the pros and cons of using ground based sensors as a means of detection. Having heard various opinions on the utility and merit of Unattended Ground Sensors (UGS) with regards to counterforce and counterfire operations against Tactical Ballistic Missile (TBM) Launchers, there is an apparent negative bias against UGS based on the perception with regard to the success of such systems in the past. Thus, we shall briefly define the arguments against UGS, and counter these arguments in an attempt to overcome this negative bias. As *The Electronic Battlefield* was used as a major resource, we shall first define "Electronic Battlefield", then examine the issues related to cost, discrimination and deployment.[4]

Author Paul Dickson presents two definitions which he terms "Electronic Battlefield I", or EB I, and "Electronic Battlefield II" (EB II). EB I refers to the first generation UGS, those of limited discrimination capability which would carry one or more of the following: seismic, acoustic, Infrared (IR), and magnetic sensors. Note that although Infrared (IR) sensors are included in this list, only limited success was achieved early in UGS development. EB II refers to second generation UGS systems, ones with enhanced discrimination capability and/or artificial intelligence, as well as a large list of new weapons enhancements not related to UGS, such as the Airborne Warning and Control System (AWACS), cruise missiles, Forward Looking Infrared (FLIR) Sensors, laser weapons, and the Integrated Battlefield Control System (IBCS). Many of these weapons developments are already deployed, while some are in various stages of development. For the purposes of our discussion, when the term UGS is used, we mean the EB II version, complete with neural network, multiple integrated sensors, decision aids to assist the user in deployment, and means for real time infusion to assist on scene assets in counterforce and counterfire operations.

Let us first examine, then, the issues relating to the cost of an UGS system which can properly carry out the TBM counterforce mission. The first argument is that an UGS system would be too costly based strictly on the pricetag for each sensor, and the fact that these are disposable assets used over wide areas requiring large numbers of sensors. While true that present costs are quite high, mass production should rapidly reduce cost, especially in the wartime scenario. For example, during the Vietnam War, the cost of an Acoustic Directional Seismic Intrusion Detector (ADSID) was reduced from $100 in 1967 to $15 in 1970 when measured by cost-per-sensor-per-day. Also, one must compare the cost of each sensor to the cost of other proposed means of detecting Transporter Erector-Launchers (TELs), such as airborne assets with their large fuel and maintenance costs. Arguments also arise over the cost of command and control of such a system and/or the cost of integrating this type of system into pre-existing systems. While this cost may be large, existing data links and those proposed to counter the TBM threat should make major expenditures unnecessary. Thus, while cost is a major issue, when compared to other alternatives, the comparative advantage of UGS seems rather clear.

Next we shall examine the issues related to UGS discrimination capabilities. Note that Vietnam era EB I systems had little or no capability to discriminate between say a truck or a jeep. The argument against UGS would then be that we might indiscriminately destroy friendly units or personnel without thought, or, if we do build in a discrimination capability, the cost would be too high, the system would not have rapid enough response time, and one might still improperly classify the sensed disturbance, whether it be human error or system error. This argument is countered by the fact that the ability of present EB II sensors with "feature vectors" processed by neural networks can rapidly identify the intended object. Even in Igloo White operations over twenty years ago, the normal time between target acquisition and weapons delivery was less than five minutes. Note also that the TEL has a rather large seismic, magnetic and acoustic signature which would make them ideal targets for such a system. This discrimination problem is really no different than that experienced by sonar operators using narrowband and broadband noise to classify contacts.

It has also been argued that deception and decoy attempts might prove successful against such neural networks. There is presently no good evidence to support such a claim, but one could surmise that the use of multiple sensors in each unit would make it very difficult to produce misclassification, as data from Lawrence Livermore National Laboratory (LLNL) would suggest. The improved capabilities of the sensors themselves with respect to sensitivity would further hinder efforts to decoy or to produce improper classification. Even if such decoy and deception techniques were successful, battlefield adaptation as well as system adaptation should make it possible to find traits unique to the decoy or deception technique to later render them useless.

We shall end our analysis with the most frequently used argument against UGS, that the successful deployment of hundreds of UGS would not yield sufficient area coverage to produce significant enhancement of mobile launcher detection probability. While it is true that motorized vehicle detection ranges are on the order of a couple hundred yards, negative search techniques and other intelligence sources should allow for optimal deployment of UGS. The lesson of the Vietnam war was that UGS capabilities were only successful when used in non-linear applications. Thus, while a barrier approach, such as the McNamara Line, was vastly unsuccessful, shorter duration operations using cuing from other sources proved highly successful, such as the alertment of the attack on Khe Sahn. The non-linear nature of TEL counterforce and counterfire operations make UGS the perfect device for such a mission.

Finally, the argument is made that UGS cannot be deployed successfully over long periods of time due to insufficient battery life, driving up the cost of the system and limiting system flexibility. While this was true of EB I sensors, the present day systems can be configured to conserve battery power by "waking up" only on certain detection features or when told to by the system. This major improvement in UGS capability allows the system to rapidly be configured to optimize detection capabilities. Thus, while arguments that UGS cannot be successfully employed have some merit, improvements in many areas make them more attractive for use in the TEL counterforce and counterfire missions.

One can easily argue that the bias against UGS is not based on present technological capabilities, but on the limited success of these systems in the past, most of which come under the classification of EB I systems. Therefore, the use of UGS in the TBM counterforce/counterfire mission should not be ruled out prematurely. Furthermore, based on the unsuccessful execution of this mission in the Gulf War using airborne and satellite assets exclusively, one can argue the need for an alternative system which has the potential to perform this mission at a lower cost with better results. As Dickson points out, "a sensor is a soldier able to do the most exacting reconnaissance work; it does not sleep, know fear, bleed, eat, or disobey."

B. **Modular Intelligent Sensor System (MISS)**

Unattended ground sensors have to be very flexible. They have to be able to allow their monitoring requirements established at the very last minute. They have to meet challenging physical environments. They must be very tamper proof. The UGS which we are going to review appear to meet all of these requirements.

Lawrence Livermore National Laboratory (LLNL) has developed an UGS called the Modular Intelligent Sensor System (MISS).[5] It has been developed around the following idea:

> "Many sensors, like many senses, enhance recognition capability".

MISS involves all of the following types of sensors:

- Seismic
- Video
- Infrared
- Magnetic
- Acoustic
- Chemical
- Nuclear.

Appendix C shows the basic components of MISS and also how a typical MISS would be connected.

MISS is an architecture for implementing modular intelligent sensors. It includes a basic bus structure, an address resolution protocol, and a communication protocol. Appendix D is a simple block diagram of MISS.

MISS can be developed to have a sensor suite that can be trained to classify specific activities. This is an incredible asset to military operations. Depending on the target which is being looked at, the system can be set up with the appropriate sensors to look only for that specific target's recognition features.

This unattended ground sensor works by using feature vectors. The feature vectors use an assortment of data obtained from each sensor in the suite. By using these feature vectors, a large amount of data can be sent in a very compact form. Appendix E shows examples of what various seismic signals would look like for aircraft activities or targets and their events. As can be seen, the sensor can distinguish between each individual event. Also in Appendix E, is an example of how the use of a geophone and a fluxgate magnetometer would be used to produce a feature vector to be analyzed.

This system can send real time data to a remote hand held monitor or to a satellite. The system can be designed to look for only certain targets and when that target is encountered, send off the signal to alert of a threat. The system uses a neural network to analyze all of the parameters of the target. The neural network allows quick analysis of the information and easy corrections to target characteristics. The real value of these sensors is that they require less data transfer, size, volume, power, and operator training.

C. Air-delivered Targeting And Surveillance System (ATASS)

The unattended ground sensor of most interest to military operations is the Air-delivered Targeting And Surveillance System (ATASS).[6] This system is being developed to provide the following:

- covert delivery and operation for long times
- seismic and magnetic baseline sensor package to provide robust, non-LOS detection and classification
- on-board neural processing to allow data fusion among multiple sensors or multiple units
- a modular architecture to permit addition of alternative sensors and changes to device thresholds or target detection algorithms
- remote, in-field reprogramming of mission parameters
- military and specialized communications capability, including GS and LEO satellite transmit/receive
- g-hardened, tested hardware to maximize reliability
- use of off-the-shelf componentry to minimize cost.

ATASS will use all of the basic components of MISS. It will be air dropped into hostile areas to monitor for specific targets.

There has been an ATASS study done at LLNL to determine the feasibility and relative success of ATASS. The assumptions that have been made for the study are:

- point of insertion accuracy of 20 meters
- insertion within 10° of vertical
- ATASS package weight < 10 kg
- impact velocity between 50 and 150 m/s
- standoff range of at least 70 km

- minimum cost components
- compatible with existing delivery systems.

Appendix F shows the optimized air vehicle configuration and calculated data of the ATASS glide performance, optimized flight regime, and high-g tests.

The ATASS system could be used in numerous ways. The first is basic search method used with sonar buoys. If there is a target in a known area, it would be bracketed and localized using ATASS. ATASS could be used in conjunction with airborne sensors, tactical intelligence or space based sensors as discussed earlier. ATASS can also be used to search along well known travelled roadways. Appendix G shows an example of this concept.

Appendix H shows an example concept of operations for CAP cued by ground sensors. In this scenario, the ground sensors are used to alert aircraft to redirect their search to a different area and then the aircraft must acquire with SAR before an engagement takes place to avoid false detections.

V. **Conclusion**

Unattended ground sensors, whether the MISS or ATASS, can have a very big impact on mission performance. Appendix I shows the probability of an aircraft acquiring a TBM when using UGS with SAR. As can be seen, using UGS greatly increases the probability of detecting a TBM and its launcher.

LLNL has developed and fielded a number of unattended ground sensors for detection and classification of vehicles, aircraft, personnel and other human events. The current generation of sensors use an enabling architecture known as the Modular Intelligent Sensor System (MISS). A full-range of sensor options are available and easily interchangeable without significant changes to the bus or the system software. The deployed MISS units make use of a multi-sensor, feature vector approach to classification which allows use of the large amount of available training data to implement a fast, accurate neural network.

In development is a hardened UGS known as the Air-delivered Targeting and Surveillance System (ATASS) for missions specific to counterproliferation such as detection and targeting of mobile TBMs. Several studies are being conducted to determine the required performance and evaluate the utility of UGS in scenarios relevant to counterproliferation activities.

VI. **Suggestion for Further Study**

Both the airborne and overhead concepts previously mentioned have far reaching applications for initial cueing for UGS deployment. Both sensors have the ability to scan over a range of wavelengths. However, how should they be used and how should the data they produce be interpreted?

What is currently needed is development of system-specific indicators that may correspond to TBM related activities. What wavelengths or video processing techniques are required? How do pre-launch activities translate into indicators that are discernible to an overhead system or a wavelength tunable video system? The technology discussed is available and ready for exploitation; the challenge is determining what to look for. Modeling is required to determine wavelengths and bandwidths of concern. Once completed, satellite resolution requirements for optical imaging need to be determined.

There are still many things to be accomplished with the unattended ground sensors themselves. Detection ranges for each of the components needs to be resolved. Transmission methods and transmission times need to be established. Test and evaluation of these sensors need to be performed.

These cueing mechanisms need to be incorporated into a concept of operations for unattended ground sensors. Data transfer and analysis requirements, as well as required timelines require formulation.

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VII. Appendices

Date: 05/12/93

APPENDIX A

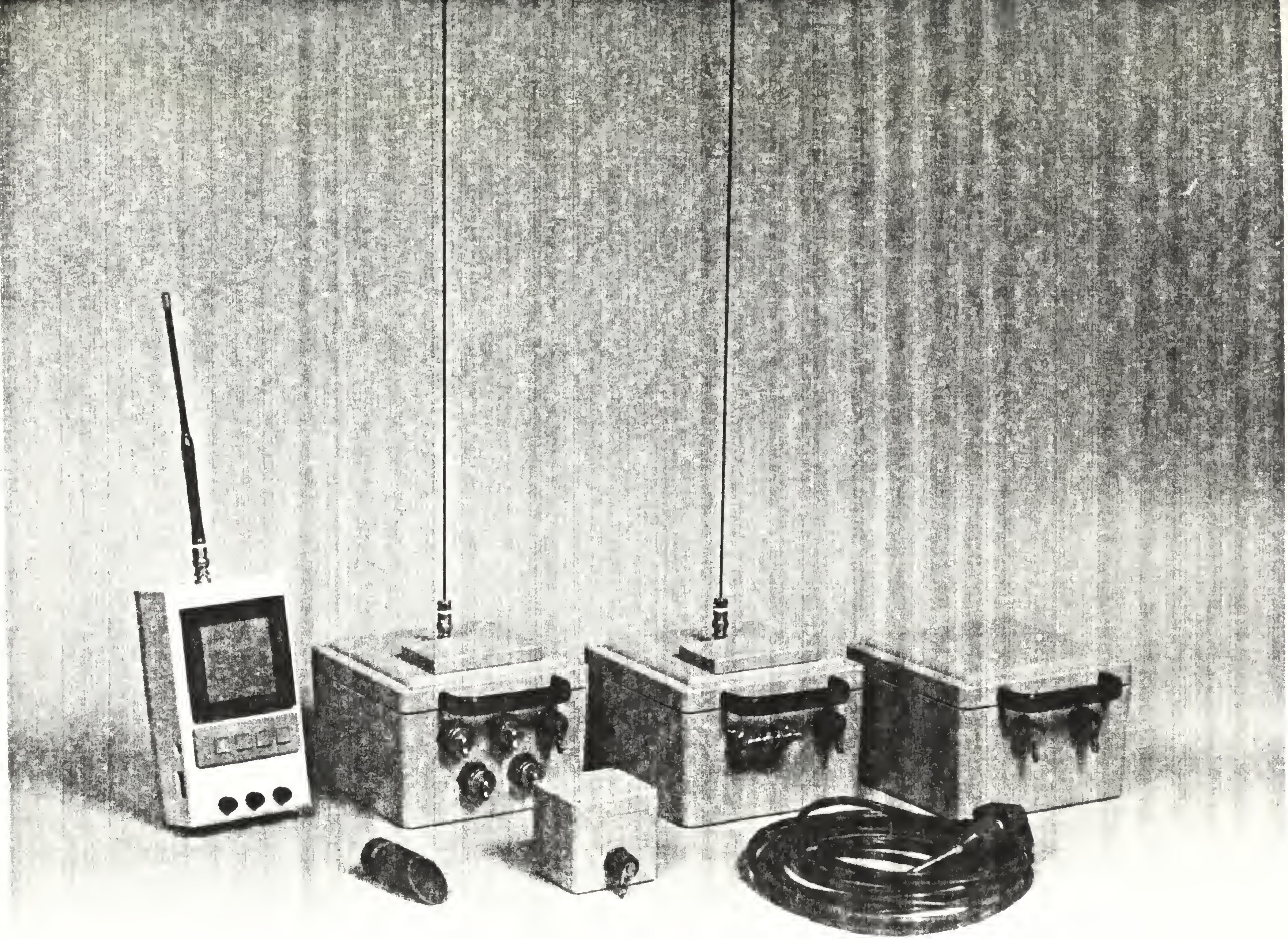
	Country	Systems
1	Afghanistan	SCUD-B
2	Algeria	SCUD-B, FROG-7
3	Argentina	Alacran, Condor 2
4	Azerbaijan	SCUD-B
5	Belarus	SS-21, SCUD-B
6	Belgium	LANCE
7	Brazil	MB/EE-150,-350,-600, -1000, SS-300, SS-1000
8	Bulgaria	SCUD-B
9	Czech Rep.	SS-21, SCUD-B
10	Egypt	SCUD-B, VECTOR, SAKR 80, SCUD-B IMP, CONDOR 2
11	France	PLUTON, HADES
12	Georgia	SCUD-B
13	Germany	LANCE
14	Hungary	SS-21, SCUD-B
15	Iran	IRAN-130, SCUD-B, SCUD-B IMP, M-18, EAGLE
16	Iraq	AL HUSAYN, ALL ABBAS, SCUD-B, SCUD-B IMP, SS-12, SS-21
17	Israel	JERICHO I & II, LANCE
18	Italy	LANCE
19	Kazakhstan	SS-21, SCUD-B
20	Kuwait	FROG-7
21	Libya	SS-21, SCUD-B, AL FATAH, LAYTH, FROG-7, MB/EE'S
22	Netherlands	LANCE
23	PRC	M-7, M-9, M-11, CSS-2, CSS-1, CSS-5, DF-25
24	PRK	NO DONG I, SCUD-B, SCUD-B IMP
25	Pakistan	HAIFT I, II, & 3
26	Poland	SS-21, SCUD-B
27	Romania	SCUD-B
28	Russia	SS-21, SCUDS A-D, FROG-7, SS-4, SS-12, SS-23
29	S. Africa	ARNISTON
30	S. Korea	KOR SSM (NHK-1)
31	Saudi Arabia	CSS-2
32	Slovakia	SS-21, SCUD-B
33	Syria	SS-21, SCUD-B, SCUD-B IMP
34	UK	LANCE
35	USA	LANCE, ATACMS
36	Ukrain	SS-21, SCUD-B
37	Vietnam	SCUD-B
38	Yemen	SS-21, SCUD-B, FROG-7

	MISSILE	RANGE	GUIDANCE	WARHEAD WT.	WARHEAD TYPE	PROPULSION	CEP	LENGTH	DIAMETER	LAUNCH WT.	LAUNCHER TYPES
1	AGNI	2500 KM	INERTIAL W/TERM	1000 KG	HE, ICM, CH	2 STAGE LIQ/SOL		18.4 M	1.3 M	16000 KG	
2	AL AABED	2000 KM	INERTIAL	750 KG	HE, CH	3 STAGF LIQ		23.0 M	2.3 M	48.000 KG	FIXED
3	AL FATAH	950 KM		500 KG							
4	AL-ABBAS	900 KM	INERTIAL	350 KG	HE, CH	1 STAGE LIQ	3 KM	13.75 M	0.88 M	8000 KG	RD MOB
5	AL-HUSAYN	650 KM	INERTIAL	500 KG	HE, CH	1 STAGE LIQ	1000 M	12.2 M	0.88 M	7000 KG	RD MOB
6	ALACRAN	200 KM	INERTIAL	500 KG	HE,CH	1 STAGE SOLID		6.9 M	0.59 M	1750 KG	FIXED
7	ARNISTON	1500 KM		1000 KG							
8	ATACMS	135 KM	INERTIAL	450 KG				3.96 M	.61 M		
9	CAPRICORNIO	1300 KM		500 KG							
10	CONDOR-I	200 KM	*1	500 KG	HE	1 STAGE SOL	*1	6.9 M	0.59 M	1750 KG	*1
11	CONDOR-II	900 KM	INERTIAL	500 KG	HE, N, CH	2 STAGESOLID	*1	11.0 M	1.0 M	6500 KG	RD MOB
12	CSS-1	1250 KM	INERTIAL	1500 KG	N	1 STAGE LIQ	*2	21 M	1.65 M	32.000 KG	FIXED
13	CSS-2, *6	2800 KM	INERTIAL, *6	2150 KG, *6	HE, N, N-MIRV	1 STAGE LIQ, *6	I KM, *6	20.62 M, *6	2.25 M, *6	27.000 KG, *6	FIXED,*1, *6
14	CSS-5,*5	1800 KM	INERTIAL	600 KG, *5	N	2 STAGE SOL	*2, *5	10.07 M, *5	1.4 M, *5	14,700 KG, *5	RD MOB
15	CSS-6,M-9	600 KM	INERTIAL W/TERM	500 KG	HE	1 STAGE SOL	300 M	9.1 M	1.0 M	6200 KG	RD MOB
16	CSS-7,M-11	300 KM	INERTIAL W/ TERM	500 KG	HE	2 STAGE SOL	*4	11.25 M	0.88 M	6350 KG	RD MOB
17	DF-25	1700 M		2000 KG		*5		*5	*5	*5	*5
18	EAGLE	40 KM			HE						
19	FROG 7	70 KM	UNGUIDED	435 KG	HE, ICM, N, CH	SOLID	500 M	9.1 M	0.54 M	2300 KG	RD MOB
20	HADES	480 KM	INERTIAL	400 KG	HE, N	1 STAGE SOL		7.5 M	0.53 M	1850 KG	RD MOB
21	HAIFT 3	600 KM		500 KG							
22	HATF-I	80 KM	INERTIAL	500 KG	HE, CH	SOL		6.0 M	0.55 M	1500 KG	RD MOB
23	HATF-II	300 KM	INERTIAL	500 KG	HE, CH	2 STAGE SOL		9.75 M	0.82 M	5500 KG	RD MOB
24	HONEST JOHN	40 KM		500 KG	HE	SOLID					
25	IRAN-130	130 KM		500 KG	HE	SOLID					RD MOB
26	JERICHO 2	1500 KM	INERTIAL	1000 KG	HE,N	2 STAGE SOL		12.0 M	1.2 M	6500 KG	RD MOB
27	JERICHO I	500 KM	INERTIAL	500 KG	HE, N, CH	2 STAGE SOL	*1	10.0 M	1.0 M	4500 KG	MOB
28	KOR SSM	250 KM		300 KG	HE	2 STAGE SOL					
29	LANCE	130 KM	INERTIAL	450 KG	HE, ICM, N	1 STAGE LIQ	150 M	6.41 M	0.56 M	1527 KG	RD MOB
30	LAYTH	90 KM	INERTIAL	435 KG	ICM	SOL	500 M	9.1 M	0.54 M	2300 KG	RD MOB
31	M-18	1000 KM		400 KG							
32	MB/EE-1000	1000 KM			HE	SOLID					
33	MB/EE-150	145 KM	INERTIAL	500 KG	HE	SOLID		12.0 M	0.7 M	4500 KG	
34	MB/EE-350	345 KM			HE	SOLID					
35	MB/EE-600	595 KM			HE	SOLID					
36	NO DONG 1	1000 KM		1000 KG	HE						
37	PERSHING I	740 KM	INERTIAL		N	2 STAGE SOL	150 M	10.55 M	1.02 M	4600 KG	RD MOB
38	PERSHING II	1853 KM	INERTIAL W/RAC		N	2 STAGE SOL	<50 M	10.6 M	1.02 M	7400 KG	RD MOB
39	PLUTON	120 KM	INERTIAL	*1	HE, N	1 STAGE SOL	150 M	7.64 M	0.65 M	2423 M	RD MOB
40	PRITHVI	250 KM	INERTIAL	500 KG	HE,ICM, FAE POSS	1 STAGE LIQ	250 M	10.0 M	1.1 M	4000 KG	RD MOB
41	ROHINI	130 KM		400 KG							
42	SAKR 80	80 KM		204 KG	HE	2 STAGE SOL					
43	SCUD-A	180 KM	INERTIAL		N	1 STAGE LIQ	3 KM	10.7 M	0.88 M	4400 KG	RD MOB
44	SCUD-B	300 KM	INERTIAL	985 KG	HE, ICM, N, CH	1 STAGE LIQ	450 M, *3	11.25 M	0.88 M	6370 KG	RD MOB,FIXED
45	SCUD-B IMP	305 KM	INERTIAL	1000 KG	HE	1 STAGE LIQ	900 M	*4	*4	*4	*4
46	SCUD-C	550 KM	INERTIAL	600 KG	HE	1 STAGE LIQ	700 M	12.0 M	0.88 M	7000 KG	RD MOB
47	SCUD-D	300 KM	INERTIAL W/AR	985 KG	HE, N, CH	1 STAGE LIQ	50 M	11.25 M	0.88 M	6350 KG	RD MOB
48	SS-1000	1000 KM			HE	SOLID					
49	SS-12	900 KM	INERTIAL W/ TERM	*4	HE, N	2 STAGE SOL	30 M	12.38 M	0.94 M	9400 KG	RD MOB
50	SS-21,*7	120 KM	INERTIAL ARTH	482 KG	HE,ICM,CH,N	1 STAGE SOL	30 M	6.4 M	0.65 M	2700 KG	RD MOB
51	SS-23, *7	500 KM	INERTIAL W/AR	450 KG	ICM, CH, N	1 STAGE SOL	30 M	7.52 M	0.89 M	4690 KG	RD MOB
52	SS-300	300 KM	INERTIAL	1000 KG	HE	LIQUID		11.25 M	0.9 M	6400 KG	RD MOB
53	SS-4	2000 KM	INERTIAL		N	LIQ, *4	2.4 KM	22.77 M	1.65 M	27,000 KG	FIXED
54	SS-600	600 KM	INERTIAL	500 KG	HE	2 STAGE SOL		11.0 M	1.0 M	7270 KG	RD MOB
55	VECTOR	600 KM		450 KG	HE	SOLID					

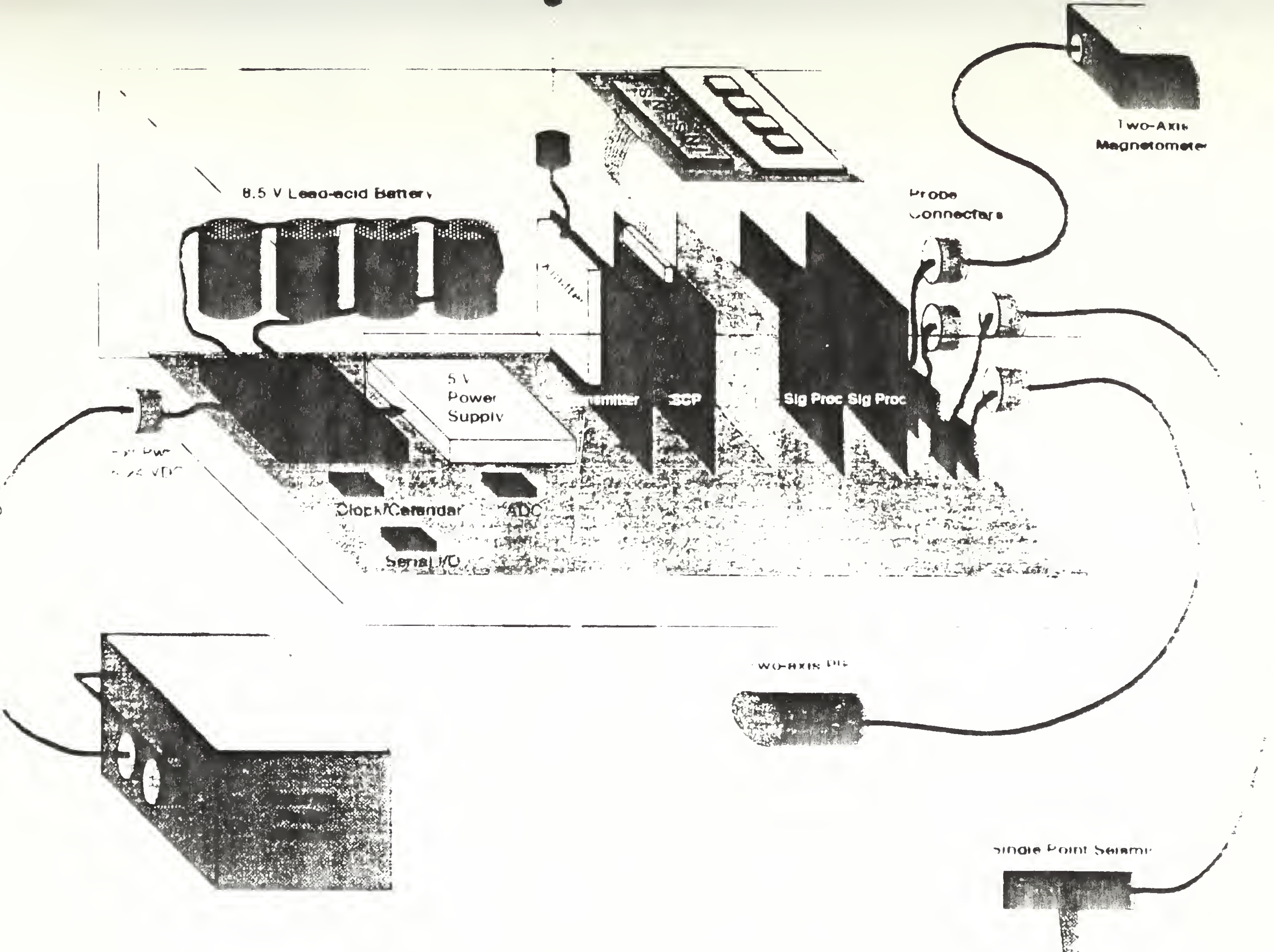
Date: 06/12/93

APPENDIX B

MISSILE	SP OR TOWED	TIME TO PREPARE FOR LAUNCH	TIME MISSILE CAN STAY READY	TIME TO DEPART LAUNCH SITE	LAUNCH FOOTPRINT	SOURCE
AGNI						INDIA
AL AABED						IRAQ
AL FATAH						LIBYA
AL-ABBAS	SP					IRAQ
AL-HUSAYN	SP TEL					IRAQ
ALACRAN						ARGENTINA
ARNISTON						SOUTH AFRICA
ATACMS						US
CAPRICORNIO						SPAIN
CONDOR-I	*1					ARGENTINA
CONDOR-II	SP					ARG/EGYPT/IRAQ
CSS-1		*2				PRC
CSS-2, *6	*1, *6	*1,*2				PRC
CSS-5,*5	SP	*2, *5, *6				PRC
CSS-6,M-9	SP					PRC
CSS-7,M-11	SP					PRC
DF-25						PRC
EAGLE						IRAN/PRK
FROG 7	SP	*4				USSR
HADES	SP					FRANCE
HAIFT 3						PAKISTAN
HATF-I	TOWED					PAKISTAN
HATF-II	TOWED					PAKISTAN
HONEST JOHN						US
IRAN-130						IRAN/PRC
JERICHO 2						ISRAEL
JERICHO I	SP	*1				ISRAEL
KOR SSM						SOUTH KOREA
LANCE	SP	*1				US
LAYTH						LIBYA
M-18						PRC/IRAN
MB/EE-1000						BRAZIL
MB/EE-150						BRAZIL
MB/EE-350						BRAZIL
MB/EE-600						BRAZIL
NO DONG 1						PRK
PERSHING I	SP TEL	*1				US
PERSHING II	SP					US
PLUTON	SP	*1				FRANCE
PRITHVI	SP					INDIA
ROHINI						INDIA
SAKR 80						EGYPT/ARG/PRK
SCUD-A	SP	*2				USSR
SCUD-B	SP TEL	*1				USSR
SCUD-B IMP	*4					EGYPT/PRK
SCUD-C	SP					USSR
SCUD-D	SP					USSR
SS-1000						BRAZIL
SS-12	SP	*4				USSR
SS-21,*7	SP, *4, *7	15 MIN, *7				USSR
SS-23, *7	*2, 87	15 MIN				USSR
SS-300	SP					BRAZIL
SS-4		*2, *4				USSR
SS-600	SP					BRAZIL
VECTOR						EGYPT/ARGENTINA

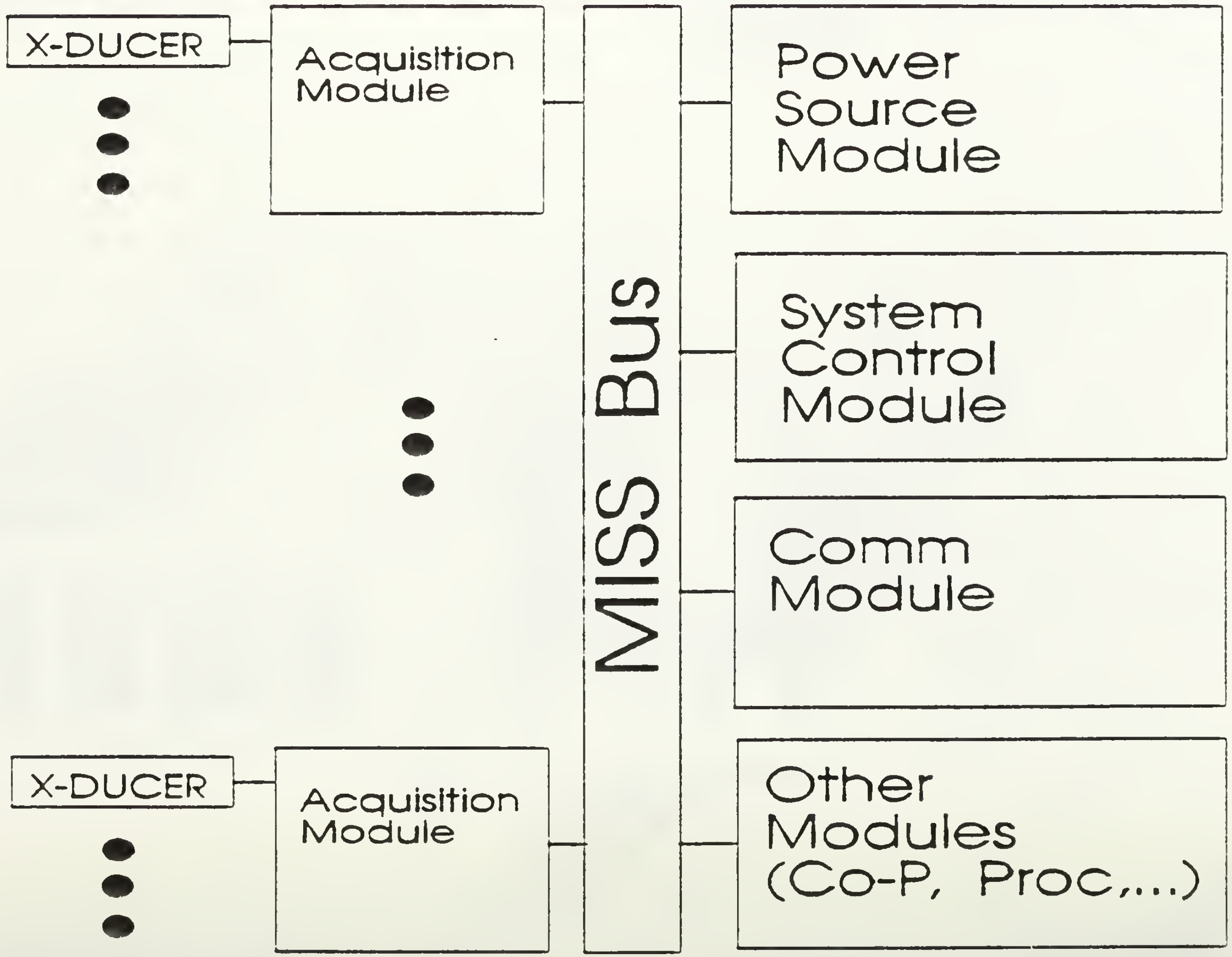


INSENS Sensor System

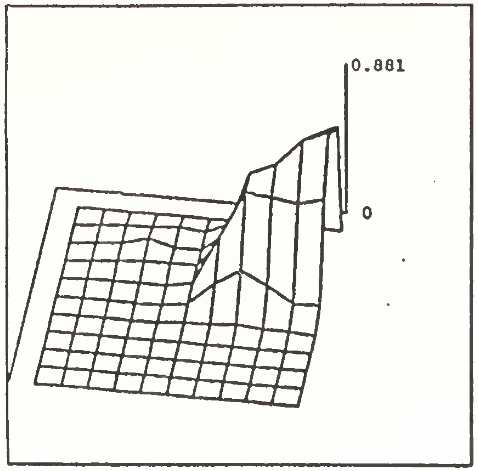


INSENS Sensor System

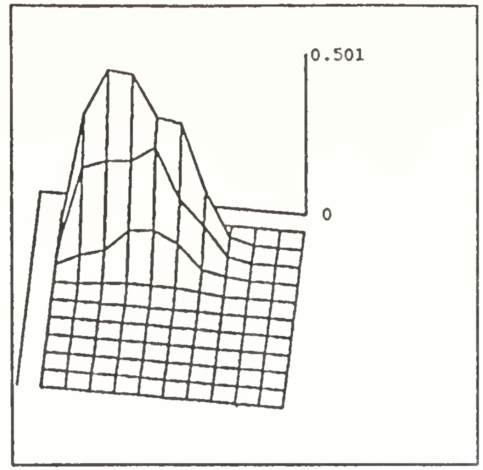
MISS Block Diagram



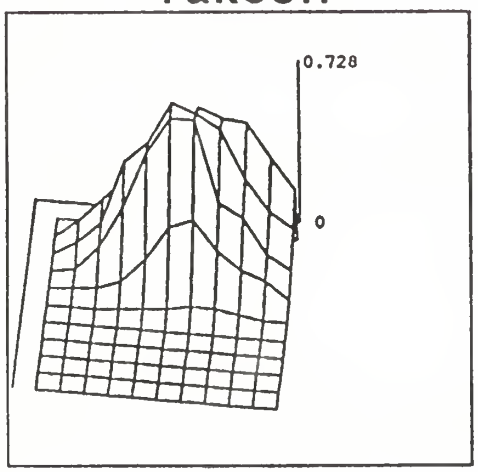
Classification of aircraft activities



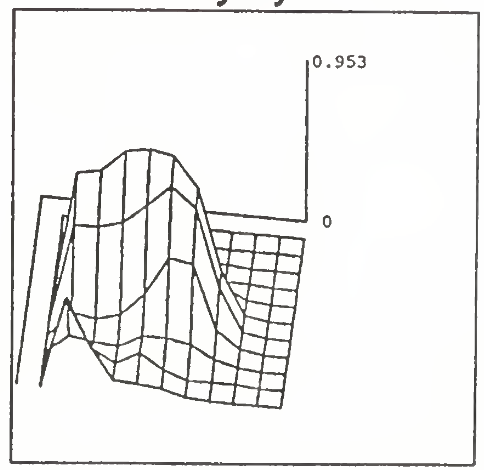
Takeoff



Flyby



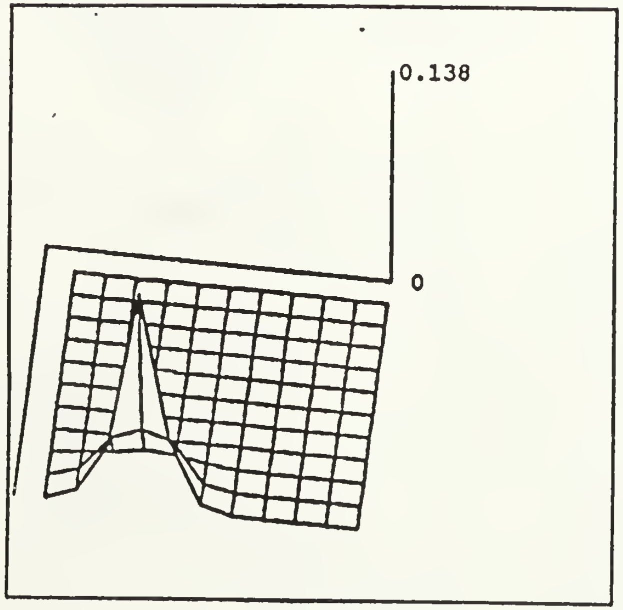
Landing

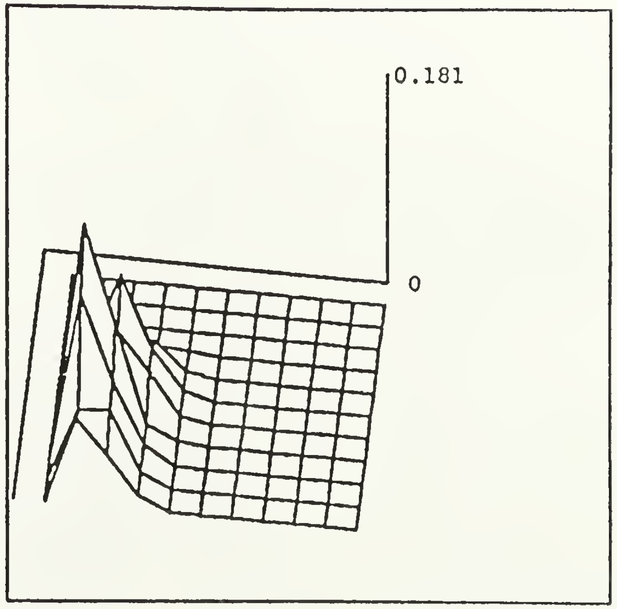


Taxi

Seismic signatures of aircraft activities showing amplitude vs. a duration plane.

Classification of targets or events



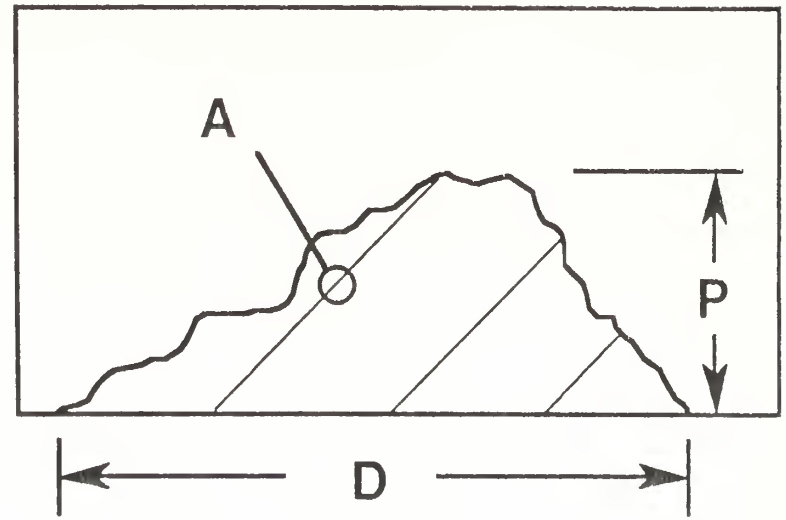


People | **Explosion**

Seismic signatures of targets or events showing amplitude vs. a duration plane.

Example: simultaneous use of geophones and fluxgate magnetometers

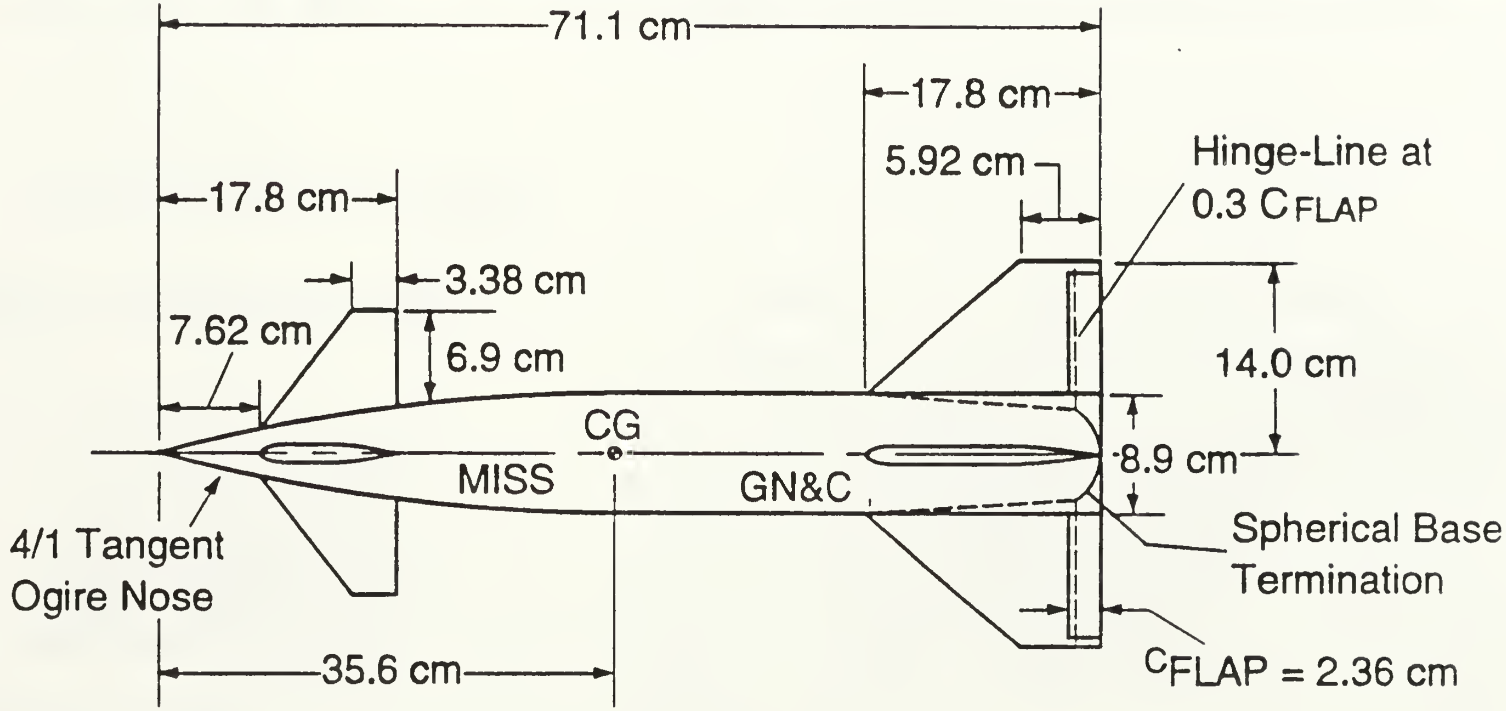
- Seismic data
  - duration
  - area under curve
  - peak signal



- Electromagnetic data
  - time integral of curl H

$$\int_t \Delta \times \mathbf{H} \; dt = \int_t \frac{\partial H_z}{\partial y} - \frac{\partial H_y}{\partial z} \, dt \quad \text{along x axis}$$

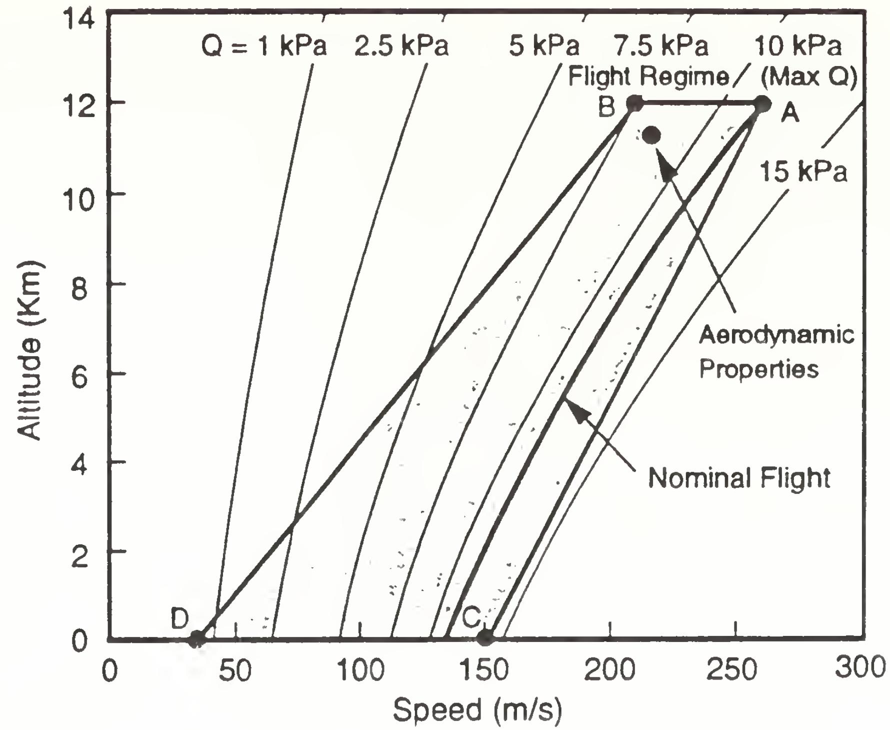
OPTIMIZED AIR VEHICLE CONFIGURATION



- Reduced fin area results in flight times < 400s
- Airfoils redesigned to reduce manufacturing complexity
- Maximum L/D is now 5.0 at 4° angle of attack

COG 93-095 30

OPTIMIZED VEHICLE FLIGHT REGIME



- Optimized configuration has less drag Consequence is higher speed trajectory
- Energy must be reduced prior to impact to achieve impact velocity requirements

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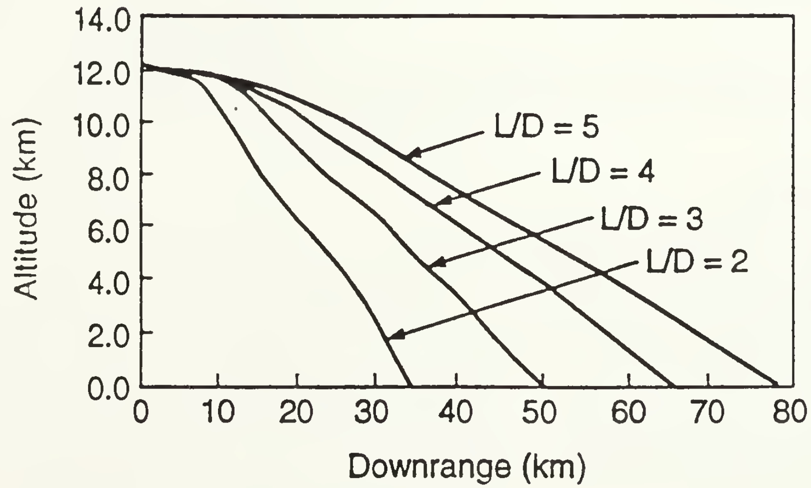
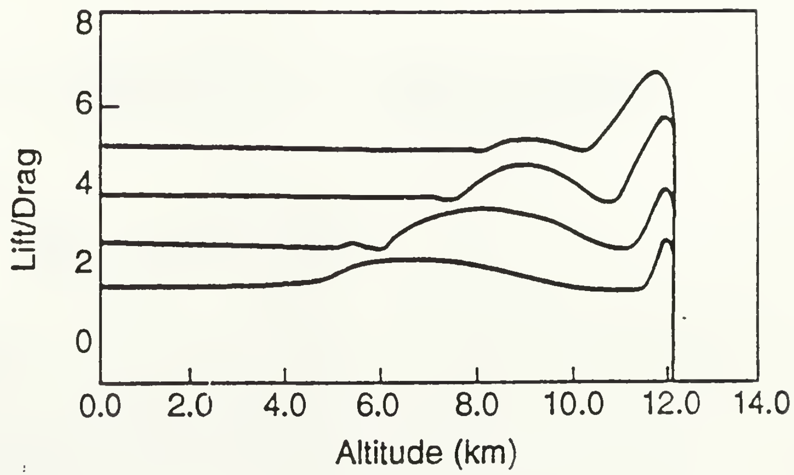
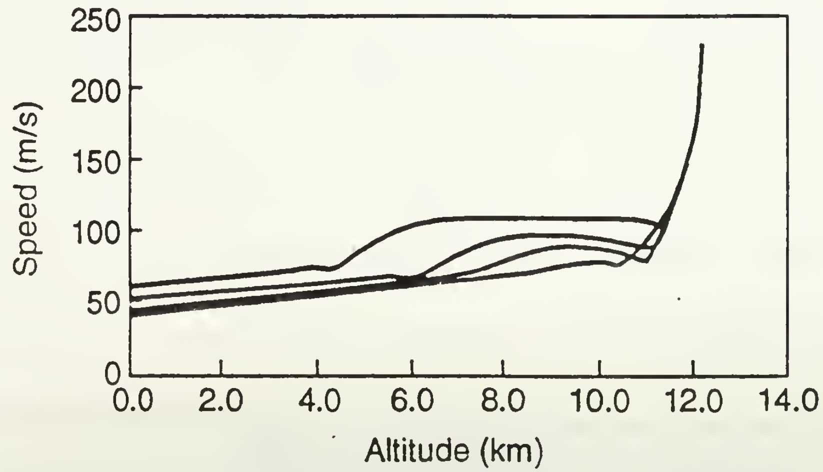
Glide bomb-like ATASS performance

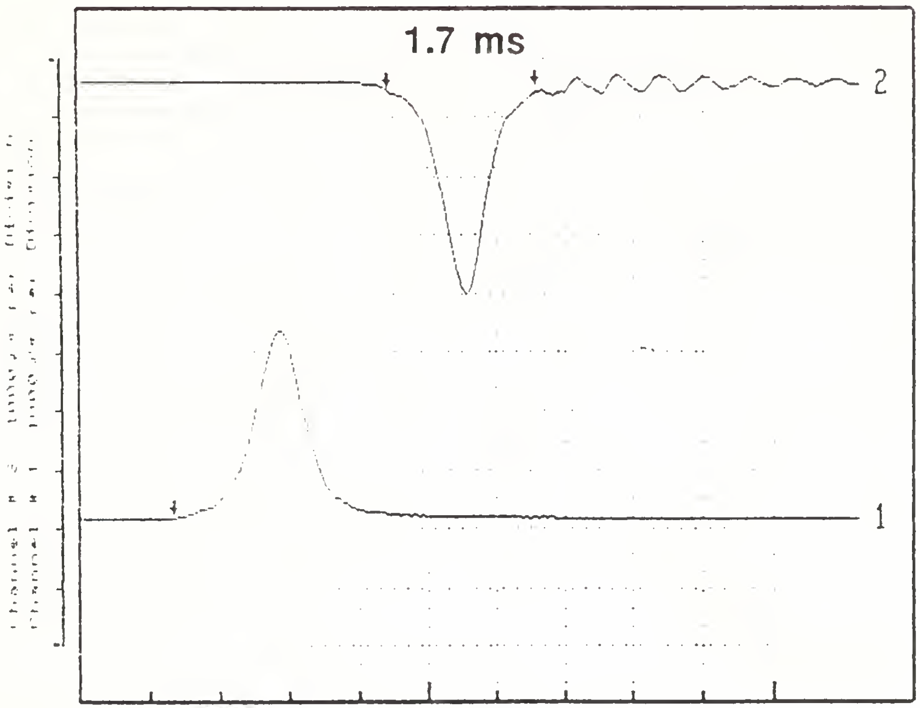




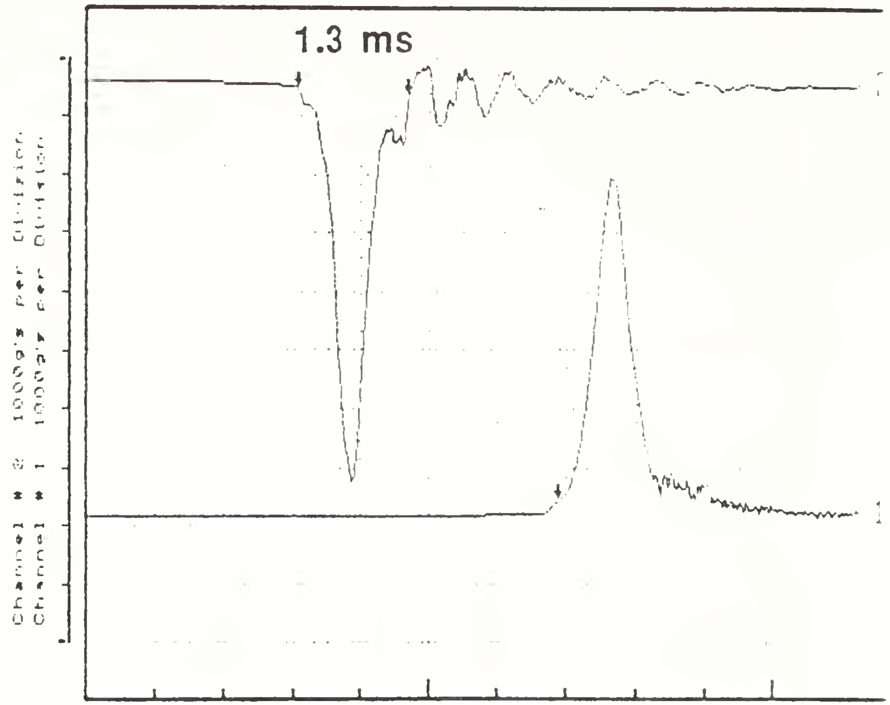


- Simulated 40 kft drop altitude at Mach 0.9
- Varied normal force coefficient to increase lift
- Results show non-optimized trajectories which perform maximum pull-up, but no dive. Optimized results with dive should be similar

MISS high-g tests: 9/20/93

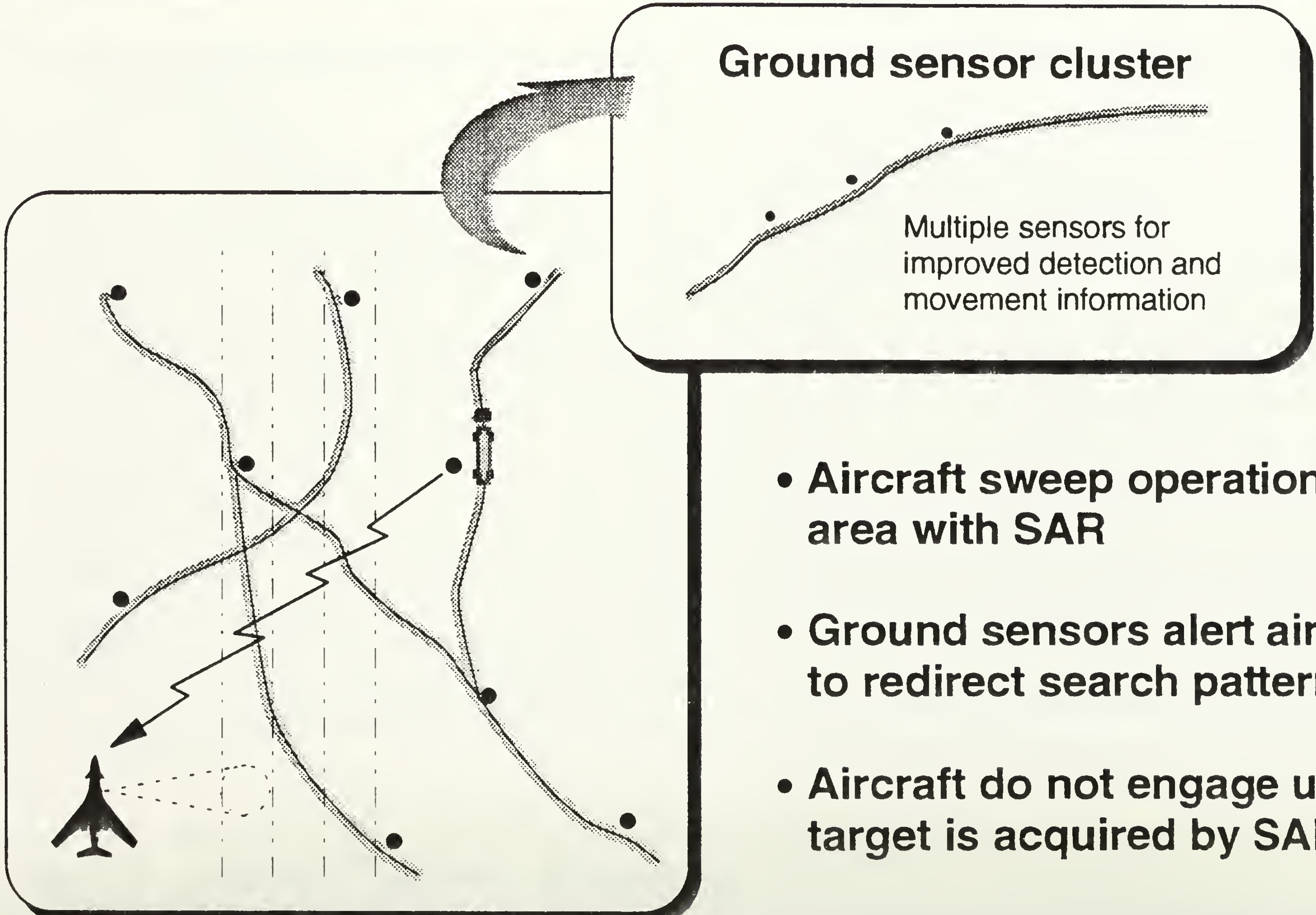


test 3 - 3300 g's



test 5 - 6500 g's

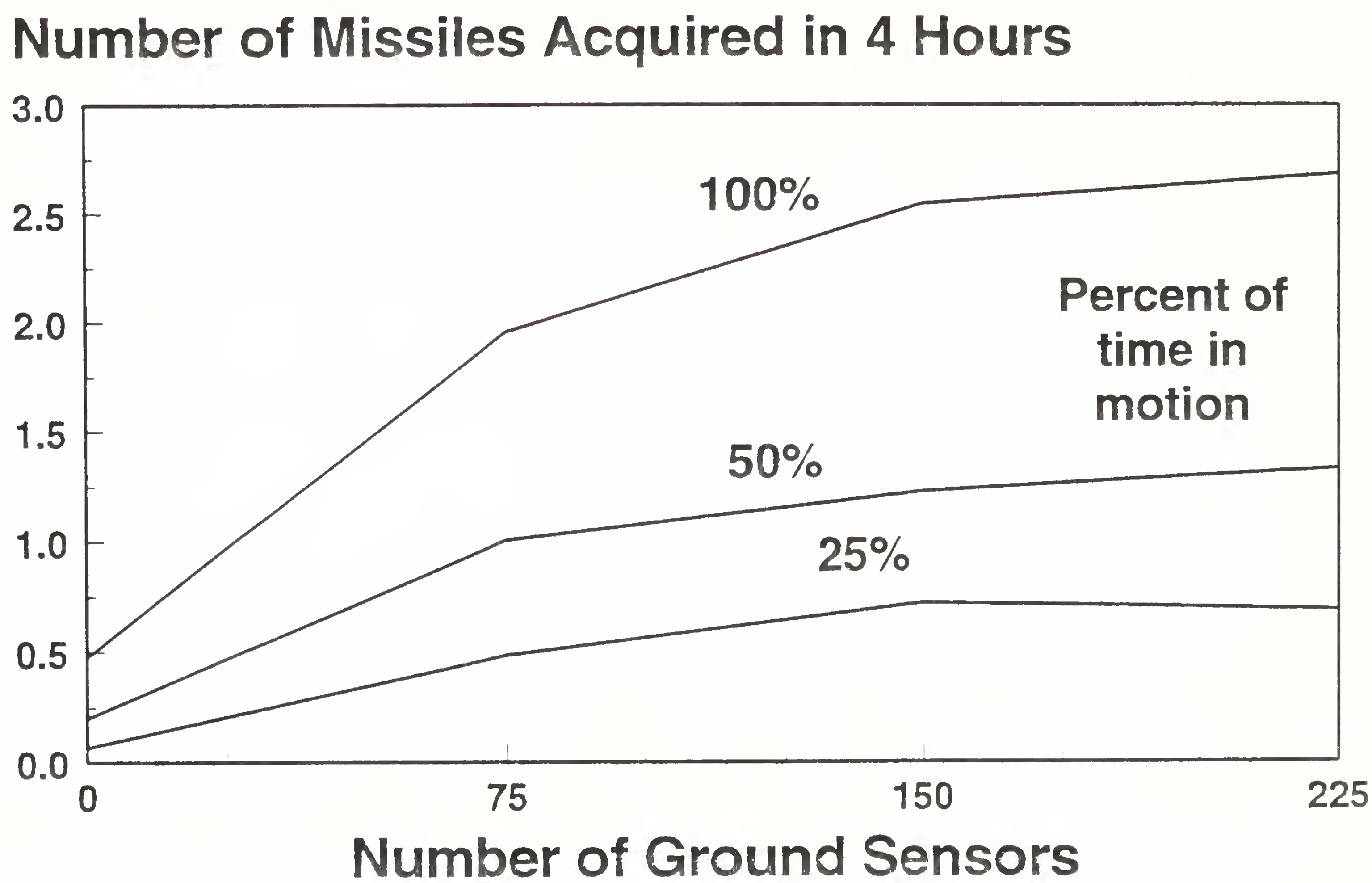
Example concept of operations for CAP cued by ground sensors



- Aircraft sweep operations area with SAR
- Ground sensors alert aircraft to redirect search pattern
- Aircraft do not engage unless target is acquired by SAR

Effect of TEL movement patterns

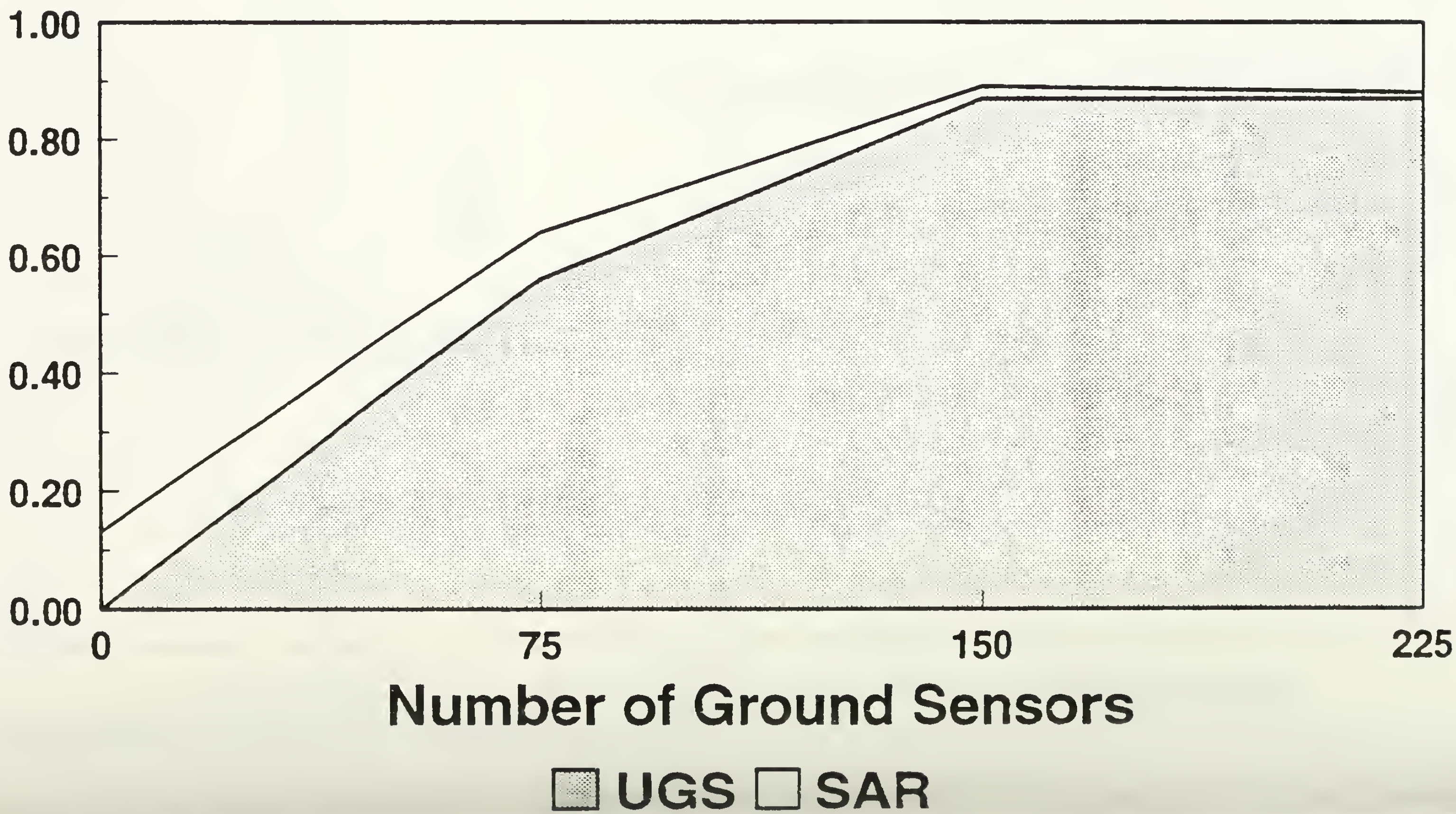
- 3 Missiles in Aircraft Patrol Zone -



Impact of Ground Sensors on Mission Performance

- Performance during a 4 hour patrol of TEL operating area
- Assumes one TEL is in motion during the sweep of the operating area

Probability Aircraft Acquires the Missile



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